# OIL OUTFLOW ANALYSIS

for a

# SERIES OF DOUBLE HULL TANKERS

**March 31, 1998**

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**U.S. Coast Guard**

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**Overview**

The BLG (Bulk Liquids and Gases) Sub-Committee is currently developing an accidental oil outflow regulation [1, 2] that will replace current hypothetical outflow and tank size requirements contained in MARPOL Regulation I/22-24.  The calculation methodology for this *"Accidental Oil Outflow"* regulation is substantially complete.  The draft regulation is performance-based, and the next step in the regulatory development process is to establish the standard or level of performance that will be expected from future tankers.  In this study the proposed calculation methodology is applied to a series of double hull tanker designs, which cover a broad range of sizes, cargo tank arrangements, and wing tank and double bottom dimensions.

**Designs Evaluated**

A matrix representing the 96 designs evaluated in this study is presented in Table 1.  Within each size range, the cargo tank configurations were evaluated with each of the three assumed double hull dimensions.  The four reference designs from the *IMO Guidelines* for evaluating alternatives to double hull tankers [3] are highlighted with bold text.

| | **Cargo Deadweight at 98% Filling  (MT)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **5,000** | 40,000 | **60,000** | 100,000 | **150,000** | 220,000 | **283,000** | 350,000 | 450,000 |
| Wing Tk. Width | **1.0 x 1.1** | 2.0 x 2.0 | **2.0 x 2.0** | 2.0 x 2.0 | **2.0 x 2.32** | 2.5 x 2.5 | **4.0 x 2.0** | 3.0 x 3.0 | 3.0 x 3.0 |
| x D.B. Height | 1.25 x 1.25 | 2.25 x 2.25 | 2.25 x 2.25 | 2.5 x 2.5 | 2.5 x 2.5 | 3.0 x 3.0 | 3.0 x 3.0 | 3.5 x 3.5 | 3.5 x 3.5 |
| (m x m) | 1.5 x 1.5 | 2.5 x 2.5 | 2.5 x 2.5 | 3.0 x 3.0 | 3.0 x 3.0 | 3.5 x 3.5 | 3.5 x 3.5 | 4.0 x 4.0 | 4.0 x 4.0 |
| Cargo Tank | 5 x 2 | 5 x 2 | 5 x 2 | 5 x 2 | 5 x 2 | 6 x 2 | **5 x 3** | 5 x 3 | 5 x 3 |
| Arrangement | **6 x 2** | 6 x 2 | **6 x 2** | 6 x 2 | **6 x 2** | 7 x 2 | 6 x 3 | 6 x 3 | 6 x 3 |
| (Long'l x | 7 x 2 | 7 x 2 | 7 x 2 | 7 x 2 | 7 x 2 | 5 x 3 | 5 x 4 | 5 x 4 | 5 x 4 |
| Transverse) | | | | | 5 x 3 | 6 x 3 | 5 x 5 | 5 x 5 | 5 x 5 |
| No. of Designs | 9 | 9 | 9 | 9 | 12 | 12 | 12 | 12 | 12 |

**Table 1**
**Matrix of Ship Sizes and Configurations**

The total cargo oil capacity is identical for all designs of a given size.  For each design, all cargo tanks are of equal length.  In addition to the cargo tanks, a pair of slop tanks are provided with a combined capacity equal to about 2.0% to 2.5% of the total cargo capacity.

A typical 6x2 (6 tanks long by two tanks wide) cargo tank arrangement is shown in Figure 1.  For all designs, "L" type ballast tanks are used, with the fore and aft ballast tank boundaries aligning with the cargo tank transverse bulkheads.  The aft-most ballast tank P/S extends longitudinally below the slop tank and the adjacent cargo tank.

The assumed spacing of longitudinal bulkheads is shown in Figure 2.

A baseline design was selected for each ship size (see Table 2).  Design characteristics such as the hull lines, the tapering of the longitudinal bulkheads fore and aft, and the locations of the collision and engine room bulkheads are consistent with modern practice.
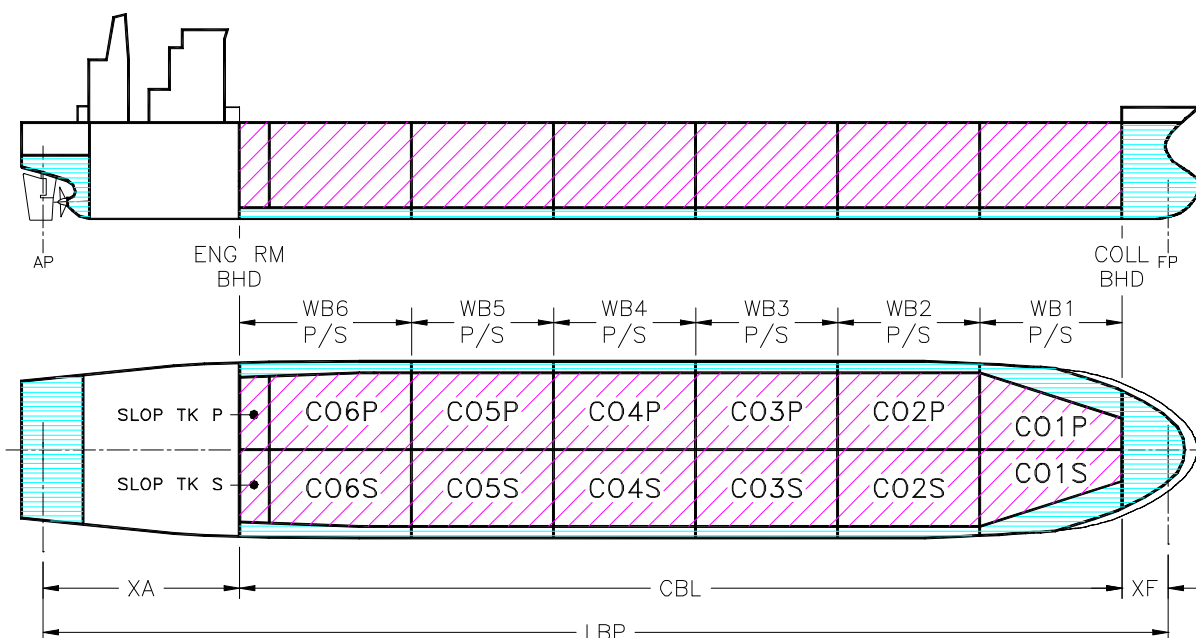
Oil Outflow Analysis for a Series of Double Hull Tankers
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**Figure 1**
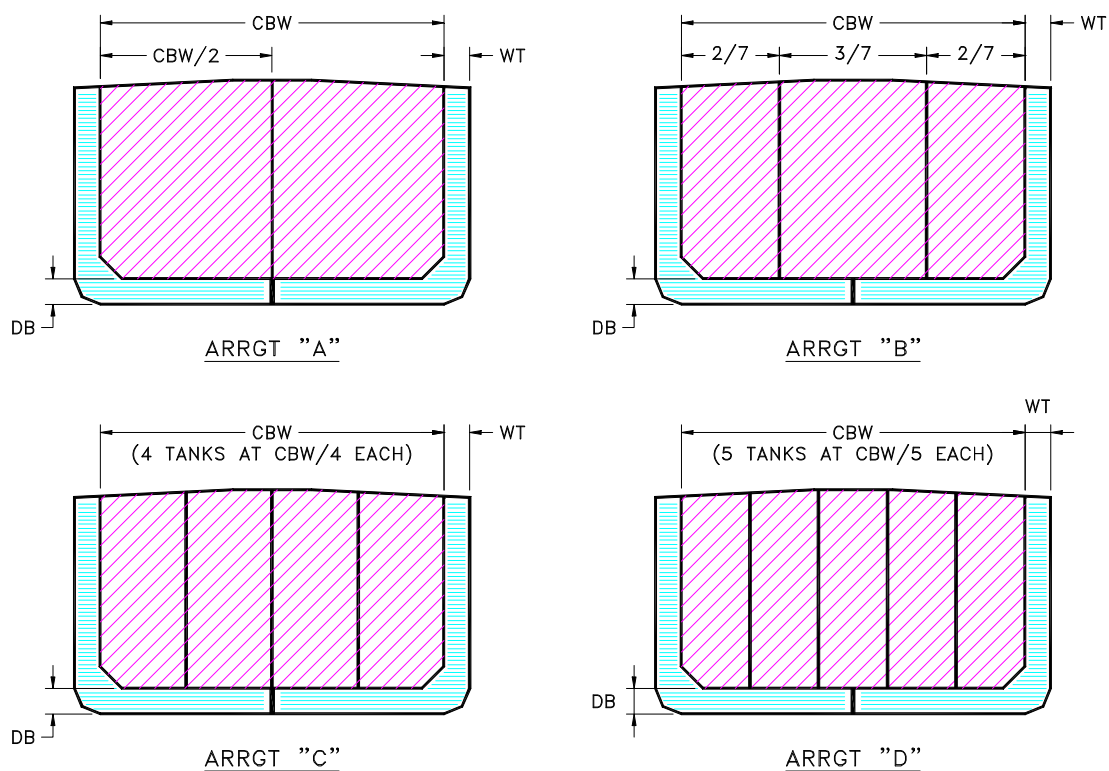**Typical 6x2 Cargo Tank Arrangement**



**Figure 2**
**Midship Sections**

A nominal cargo oil density of 0.855 t/m$^3$ is assumed for all designs.  The assumed summer load line draft for each baseline design corresponds to a condition with cargo tanks and slop tanks loaded to 98% capacity plus 50% consumables.

| Cargo Deadweight (MT) | | **5,000** | 40,000 | **60,000** | 95,000 | **150,000** | 220,000 | **283,000** | 350,000 | 450,000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cargo Tank Arrg't | | 6x2 | 6x2 | 6x2 | 6x2 | 6x2 | 6x2 | 5X3 | 5X3 | 5X3 |
| Wing Tank Width | (m) | 1.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.50 | 4.00 | 3.50 | 3.50 |
| Double Bottom Ht | (m) | 1.10 | 2.00 | 2.00 | 2.00 | 2.32 | 2.50 | 2.00 | 3.50 | 3.50 |
| | | | | | | | | | | |
| LBP | (m) | 95.00 | 170.25 | 203.50 | 235.20 | 264.00 | 295.50 | 318.00 | 342.00 | 365.00 |
| Beam (molded) | (m) | 16.50 | 30.96 | 36.00 | 41.80 | 48.00 | 53.50 | 57.00 | 63.00 | 68.00 |
| Depth (molded) | (m) | 8.30 | 17.03 | 18.00 | 19.80 | 24.00 | 27.50 | 31.00 | 32.50 | 35.00 |
| Full Draft (molded) | (m) | 6.20 | 11.72 | 12.20 | 13.79 | 16.80 | 19.66 | 22.00 | 23.00 | 25.50 |
| | | | | | | | | | | |
| 98% Cargo Capacity (m$^3$) | | 5,848 | 46,784 | 70,175 | 111,111 | 175,439 | 257,310 | 330,994 | 409,357 | 526,316 |
| Cargo Oil Density (MT/m$^3$) | | 0.855 | 0.855 | 0.855 | 0.855 | 0.855 | 0.855 | 0.855 | 0.855 | 0.855 |

**Table 2**
**Baseline Design Particulars**

The other designs in a given size are extrapolated from the baseline design. The cargo block outer boundaries are assumed constant, and therefore the cargo volume remains unchanged.  The beam and depth is reduced or increased as required to accommodate changes in double hull dimensions.  The LBP is held constant.  The block coefficient is adjusted to maintain constant draft.

The outer longitudinal bulkheads are sloped inboard fore and aft, in order to maintain the designated clearances.  Typically, the nominal wing tank clearance is maintained in way of the parallel midbody and at the ends of the cargo block.  Due to the shape of the hull in contrast to the flat plane of the bulkhead, the clearances typically exceed the nominal clearance towards the centers of the fore and aft cargo tanks (see Figure 1).

The increased wing tank clearances tend to improve environmental performance (i.e. reduce mean outflow and increase the probability of zero outflow).  Because these increased clearances are somewhat arbitrary and subject to a yard's practice, outflow calculations in this study assume the nominal double bottom and wing tank clearances are exactly maintained throughout the cargo block.  When calculating the probabilities of breaching the cargo tanks, a simplified prismatic hull shape was assumed (see Figure 3).
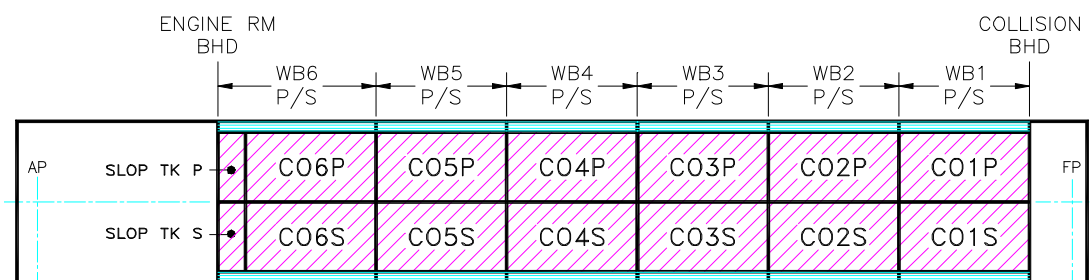


**Figure 3**
**Primatic Hull Form**
**(Assumed for Probability Calculations)**

**Oil Outflow Analysis**

Table 3 shows a comparison of the probability of zero outflow and mean outflow parameters obtained in this analysis and those published in the *IMO Guidelines* for evaluating alternatives to double hull tankers [3].

| | Cargo DWT (MTons) | Cargo Tank Arrg't | WT x DB (m) | Mean Outflow Parameter $O_M / C$ | Probability of Zero Outflow $P_0$ |
|---|---|---|---|---|---|
| As Calculated | 5,000 | 6x2 | 1.0 x 1.1 | 0.014 | 0.84 |
| Per IMO Guidelines | | | | 0.017 | 0.81 |
| As Calculated | 60,000 | 6x2 | 2.0 x 2.0 | 0.016 | 0.81 |
| Per IMO Guidelines | | | | 0.014 | 0.81 |
| As Calculated | 150,000 | 6x2 | 2.0 x 2.32 | 0.018 | 0.77 |
| Per IMO Guidelines | | | | 0.016 | 0.79 |
| As Calculated | 283,000 | 5x3 | 4.0 x 2.0 | 0.012 | 0.75 |
| Per IMO Guidelines | | | | 0.013 | 0.77 |

**Table 3**
**Outflow Parameter Comparison (with IMO Reference Ships)**

Factors contributing to the differences in results are:

▪ The draft *"Accidental Outflow Regulation"* contains certain simplifying assumptions. These include the treatment of how the capture of oil by the double bottom tanks is accounted for, and also how the pdf's are applied.

▪ The calculations in this study assume uniform wing tank and double bottom dimensions over the full extent of the cargo block, and prismatic cross-sections for the tanks.

With regard to the differences in results for the specific designs:

5,000 DWT:  The *IMO Guideline* calculations assume the damage is in the form of a vertical, rectangular block.  This design has significant flare in the outer longitudinal bulkhead forward, in order to maximize cargo volume.  The rectangular damage strikes the upper edge of the forward cargo tanks, resulting in a relative high probability of damage.  In contrast, the draft *"Accidental Outflow Regulation"* measures all damage horizontally from the shell.  This approach yields higher $P_0$ and lower mean outflow parameters.

60,000 DWT and 150,000 DWT:  In this study, a uniform wing tank width is assumed over the length of the cargo block.  In the designs analyzed for the development of the *IMO Guidelines*, the wing tank width towards the middle of the fwd cargo tanks exceeds the nominal wing tank dimension.  This tends to reduce the probability of breaching these tanks in collisions, and accounts for the lower mean outflow parameters obtained in the *IMO Guideline* calculations.

283,000 DWT:  Similarly, the uniform wing tank width results in a reduction in the  probability of zero outflow parameter.  The mean outflow parameter is in close agreement.

The oil outflow results are summarized in Tables 4 and 5.

| Cargo DWT (MTons) | Cargo Tank Arr't | WT x DB (m) | Mean Outflow (m³) Side $O_{MS}$ | Bottom $O_{MB}$ | Total $O_M$ | 98% Cap. (m³) $C$ | Mean Outf. Parameter $O_M/C$ | Prob. Zero Outflow Side $P_{0S}$ | Bottom $P_{0B}$ | Total $P_0$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 5,000 | 5x2 | 1.0 x 1.1 | 115 | 68 | 87 | 5,849 | 0.0148 | 0.847 | 0.838 | 0.842 |
| | | 1.25 x 1.25 | 89 | 61 | 72 | 5,849 | 0.0124 | 0.881 | 0.855 | 0.865 |
| | | 1.5 x 1.5 | 73 | 52 | 60 | 5,849 | 0.0103 | 0.903 | 0.880 | 0.889 |
| | 6x2 | 1.0 x 1.1 | 102 | 64 | 79 | 5,849 | 0.0136 | 0.847 | 0.838 | 0.842 |
| | | 1.25 x 1.25 | 79 | 57 | 66 | 5,849 | 0.0113 | 0.881 | 0.855 | 0.865 |
| | | 1.5 x 1.5 | 65 | 49 | 55 | 5,849 | 0.0094 | 0.903 | 0.880 | 0.889 |
| | 7x2 | 1.0 x 1.1 | 93 | 61 | 74 | 5,849 | 0.0126 | 0.847 | 0.838 | 0.842 |
| | | 1.25 x 1.25 | 72 | 55 | 62 | 5,849 | 0.0106 | 0.881 | 0.855 | 0.865 |
| | | 1.5 x 1.5 | 59 | 46 | 51 | 5,849 | 0.0088 | 0.903 | 0.880 | 0.889 |
| 40,000 | 5x2 | 2.0 x 2.0 | 898 | 526 | 675 | 46,784 | 0.0144 | 0.852 | 0.820 | 0.833 |
| | | 2.25 x 2.25 | 785 | 493 | 609 | 46,784 | 0.0130 | 0.871 | 0.834 | 0.849 |
| | | 2.5 x 2.5 | 694 | 460 | 554 | 46,784 | 0.0118 | 0.885 | 0.847 | 0.863 |
| | 6x2 | 2.0 x 2.0 | 797 | 491 | 613 | 46,784 | 0.0131 | 0.852 | 0.820 | 0.833 |
| | | 2.25 x 2.25 | 696 | 460 | 555 | 46,784 | 0.0119 | 0.871 | 0.834 | 0.849 |
| | | 2.5 x 2.5 | 616 | 430 | 504 | 46,784 | 0.0108 | 0.885 | 0.847 | 0.863 |
| | 7x2 | 2.0 x 2.0 | 724 | 468 | 570 | 46,784 | 0.0122 | 0.852 | 0.820 | 0.833 |
| | | 2.25 x 2.25 | 633 | 438 | 516 | 46,784 | 0.0110 | 0.871 | 0.834 | 0.849 |
| | | 2.5 x 2.5 | 560 | 409 | 470 | 46,784 | 0.0100 | 0.885 | 0.847 | 0.863 |
| 60,000 | 5x2 | 2.0 x 2.0 | 1,680 | 894 | 1,208 | 70,175 | 0.0172 | 0.808 | 0.805 | 0.806 |
| | | 2.25 x 2.25 | 1,490 | 840 | 1,100 | 70,175 | 0.0157 | 0.830 | 0.819 | 0.823 |
| | | 2.5 x 2.5 | 1,327 | 788 | 1,003 | 70,175 | 0.0143 | 0.848 | 0.831 | 0.838 |
| | 6x2 | 2.0 x 2.0 | 1,492 | 833 | 1,096 | 70,175 | 0.0156 | 0.808 | 0.805 | 0.806 |
| | | 2.25 x 2.25 | 1,323 | 783 | 999 | 70,175 | 0.0142 | 0.830 | 0.819 | 0.823 |
| | | 2.5 x 2.5 | 1,178 | 734 | 911 | 70,175 | 0.0130 | 0.848 | 0.831 | 0.838 |
| | 7x2 | 2.0 x 2.0 | 1,357 | 793 | 1,019 | 70,175 | 0.0145 | 0.808 | 0.805 | 0.806 |
| | | 2.25 x 2.25 | 1,204 | 745 | 929 | 70,175 | 0.0132 | 0.830 | 0.819 | 0.823 |
| | | 2.5 x 2.5 | 1,072 | 699 | 848 | 70,175 | 0.0121 | 0.848 | 0.831 | 0.838 |
| 95,000 | 5x2 | 2.0 x 2.0 | 3,115 | 1,367 | 2,066 | 111,111 | 0.0186 | 0.780 | 0.795 | 0.789 |
| | | 2.5 x 2.5 | 2,791 | 1,305 | 1,899 | 111,111 | 0.0171 | 0.803 | 0.808 | 0.806 |
| | | 3.0 x 3.0 | 2,512 | 1,242 | 1,750 | 111,111 | 0.0157 | 0.823 | 0.820 | 0.821 |
| | 6x2 | 2.0 x 2.0 | 2,758 | 1,275 | 1,869 | 111,111 | 0.0168 | 0.780 | 0.795 | 0.789 |
| | | 2.5 x 2.5 | 2,471 | 1,218 | 1,719 | 111,111 | 0.0155 | 0.803 | 0.808 | 0.806 |
| | | 3.0 x 3.0 | 2,224 | 1,159 | 1,585 | 111,111 | 0.0143 | 0.823 | 0.820 | 0.821 |
| | 7x2 | 2.0 x 2.0 | 2,503 | 1,211 | 1,728 | 111,111 | 0.0156 | 0.780 | 0.795 | 0.789 |
| | | 2.5 x 2.5 | 2,242 | 1,157 | 1,591 | 111,111 | 0.0143 | 0.803 | 0.808 | 0.806 |
| | | 3.0 x 3.0 | 2,018 | 1,101 | 1,468 | 111,111 | 0.0132 | 0.823 | 0.820 | 0.821 |
| 150,000 | 5x2 | 2.0 x 2.32 | 5,661 | 1,950 | 3,434 | 175,439 | 0.0196 | 0.745 | 0.791 | 0.773 |
| | | 2.5 x 2.5 | 4,540 | 1,835 | 2,917 | 175,439 | 0.0166 | 0.795 | 0.800 | 0.798 |
| | | 3.0 x 3.0 | 3,788 | 1,691 | 2,530 | 175,439 | 0.0144 | 0.829 | 0.820 | 0.824 |
| | 6x2 | 2.0 x 2.32 | 5,018 | 1,819 | 3,099 | 175,439 | 0.0177 | 0.745 | 0.791 | 0.773 |
| | | 2.5 x 2.5 | 4,025 | 1,712 | 2,637 | 175,439 | 0.0150 | 0.795 | 0.800 | 0.798 |
| | | 3.0 x 3.0 | 3,358 | 1,578 | 2,290 | 175,439 | 0.0131 | 0.829 | 0.820 | 0.824 |
| | 7x2 | 2.0 x 2.32 | 4,558 | 1,730 | 2,861 | 175,439 | 0.0163 | 0.745 | 0.791 | 0.773 |
| | | 2.5 x 2.5 | 3,656 | 1,628 | 2,439 | 175,439 | 0.0139 | 0.795 | 0.800 | 0.798 |
| | | 3.0 x 3.0 | 3,050 | 1,500 | 2,120 | 175,439 | 0.0121 | 0.829 | 0.820 | 0.824 |
| | 5x3 | 2.0 x 2.32 | 3,267 | 1,834 | 2,407 | 175,439 | 0.0137 | 0.745 | 0.791 | 0.773 |
| | | 2.5 x 2.5 | 2,620 | 1,761 | 2,105 | 175,439 | 0.0120 | 0.795 | 0.800 | 0.798 |
| | | 3.0 x 3.0 | 2,186 | 1,663 | 1,872 | 175,439 | 0.0107 | 0.829 | 0.820 | 0.824 |

**Table 4**
**Outflow Simmary (5,000 CDWT – 150,000 CDWT)**

| Cargo DWT (MTons) | Cargo Tank Arrg't | WT x DB (m) | Mean Outflow (m³) Side $O_{MS}$ | Bottom $O_{MB}$ | Total $O_M$ | 98% Cap. (m³) $C$ | Mean Outf. Parameter $O_M/C$ | Prob. Zero Outflow Side $P_{0S}$ | Bottom $P_{0B}$ | Total $P_0$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 220,000 | 6x2 | 2.5 x 2.5 | 6,549 | 2,358 | 4,034 | 257,310 | 0.0157 | 0.775 | 0.780 | 0.778 |
| | | 3.0 x 3.0 | 5,509 | 2,160 | 3,500 | 257,310 | 0.0136 | 0.811 | 0.804 | 0.806 |
| | | 3.5 x 3.5 | 4,687 | 2,016 | 3,084 | 257,310 | 0.0120 | 0.839 | 0.821 | 0.828 |
| | 7x2 | 2.5 x 2.5 | 5,943 | 2,237 | 3,719 | 257,310 | 0.0145 | 0.775 | 0.780 | 0.778 |
| | | 3.0 x 3.0 | 5,000 | 2,049 | 3,229 | 257,310 | 0.0125 | 0.811 | 0.804 | 0.806 |
| | | 3.5 x 3.5 | 4,254 | 1,911 | 2,848 | 257,310 | 0.0111 | 0.839 | 0.821 | 0.828 |
| | 5x3 | 2.5 x 2.5 | 4,254 | 2,151 | 2,992 | 257,310 | 0.0116 | 0.775 | 0.780 | 0.778 |
| | | 3.0 x 3.0 | 3,578 | 1,984 | 2,622 | 257,310 | 0.0102 | 0.811 | 0.804 | 0.806 |
| | | 3.5 x 3.5 | 3,044 | 1,864 | 2,336 | 257,310 | 0.0091 | 0.839 | 0.821 | 0.828 |
| | 6x3 | 2.5 x 2.5 | 3,769 | 2,012 | 2,715 | 257,310 | 0.0106 | 0.775 | 0.780 | 0.778 |
| | | 3.0 x 3.0 | 3,171 | 1,855 | 2,381 | 257,310 | 0.0093 | 0.811 | 0.804 | 0.806 |
| | | 3.5 x 3.5 | 2,698 | 1,742 | 2,124 | 257,310 | 0.0083 | 0.839 | 0.821 | 0.828 |
| 283,000 | 5x3 | 4.0 x 2.0 | 3,433 | 4,175 | 3,878 | 330,994 | 0.0117 | 0.858 | 0.686 | 0.755 |
| | | 3.0 x 3.0 | 4,671 | 3,395 | 3,905 | 330,994 | 0.0118 | 0.807 | 0.787 | 0.795 |
| | | 3.5 x 3.5 | 3,980 | 3,226 | 3,527 | 330,994 | 0.0107 | 0.836 | 0.806 | 0.818 |
| | 6x3 | 4.0 x 2.0 | 3,041 | 3,894 | 3,553 | 330,994 | 0.0107 | 0.858 | 0.686 | 0.755 |
| | | 3.0 x 3.0 | 4,138 | 3,166 | 3,555 | 330,994 | 0.0107 | 0.807 | 0.787 | 0.795 |
| | | 3.5 x 3.5 | 3,526 | 3,009 | 3,216 | 330,994 | 0.0097 | 0.836 | 0.806 | 0.818 |
| | 5x4 | 4.0 x 2.0 | 3,157 | 3,056 | 3,097 | 330,994 | 0.0094 | 0.858 | 0.686 | 0.755 |
| | | 3.0 x 3.0 | 4,320 | 2,550 | 3,258 | 330,994 | 0.0098 | 0.807 | 0.787 | 0.795 |
| | | 3.5 x 3.5 | 3,674 | 2,381 | 2,898 | 330,994 | 0.0088 | 0.836 | 0.806 | 0.818 |
| | 5x5 | 4.0 x 2.0 | 3,129 | 3,577 | 3,398 | 330,994 | 0.0103 | 0.858 | 0.686 | 0.755 |
| | | 3.0 x 3.0 | 4,056 | 3,113 | 3,490 | 330,994 | 0.0105 | 0.807 | 0.787 | 0.795 |
| | | 3.5 x 3.5 | 3,541 | 3,033 | 3,236 | 330,994 | 0.0098 | 0.836 | 0.806 | 0.818 |
| 350,000 | 5x3 | 3.0 x 3.0 | 6,600 | 3,481 | 4,729 | 409,357 | 0.0116 | 0.779 | 0.785 | 0.783 |
| | | 3.5 x 3.5 | 5,706 | 3,340 | 4,286 | 409,357 | 0.0105 | 0.809 | 0.803 | 0.806 |
| | | 4.0 x 4.0 | 4,960 | 3,226 | 3,920 | 409,357 | 0.0096 | 0.834 | 0.818 | 0.825 |
| | 6x3 | 3.0 x 3.0 | 5,843 | 3,246 | 4,284 | 409,357 | 0.0105 | 0.779 | 0.785 | 0.783 |
| | | 3.5 x 3.5 | 5,051 | 3,114 | 3,889 | 409,357 | 0.0095 | 0.809 | 0.803 | 0.806 |
| | | 4.0 x 4.0 | 4,392 | 3,007 | 3,561 | 409,357 | 0.0087 | 0.834 | 0.818 | 0.825 |
| | 5x4 | 3.0 x 3.0 | 6,104 | 2,544 | 3,968 | 409,357 | 0.0097 | 0.779 | 0.785 | 0.783 |
| | | 3.5 x 3.5 | 5,275 | 2,394 | 3,546 | 409,357 | 0.0087 | 0.809 | 0.803 | 0.806 |
| | | 4.0 x 4.0 | 4,579 | 2,269 | 3,193 | 409,357 | 0.0078 | 0.834 | 0.818 | 0.825 |
| | 5x5 | 3.0 x 3.0 | 5,624 | 3,103 | 4,112 | 409,357 | 0.0100 | 0.779 | 0.785 | 0.783 |
| | | 3.5 x 3.5 | 4,964 | 3,045 | 3,813 | 409,357 | 0.0093 | 0.809 | 0.803 | 0.806 |
| | | 4.0 x 4.0 | 4,409 | 3,005 | 3,567 | 409,357 | 0.0087 | 0.834 | 0.818 | 0.825 |
| 450,000 | 5x3 | 3.0 x 3.0 | 9,293 | 4,376 | 6,343 | 526,316 | 0.0121 | 0.757 | 0.766 | 0.762 |
| | | 3.5 x 3.5 | 8,012 | 4,053 | 5,636 | 526,316 | 0.0107 | 0.791 | 0.793 | 0.792 |
| | | 4.0 x 4.0 | 7,027 | 3,944 | 5,177 | 526,316 | 0.0098 | 0.816 | 0.807 | 0.811 |
| | 6x3 | 3.0 x 3.0 | 8,225 | 4,078 | 5,737 | 526,316 | 0.0109 | 0.757 | 0.766 | 0.762 |
| | | 3.5 x 3.5 | 7,091 | 3,777 | 5,102 | 526,316 | 0.0097 | 0.791 | 0.793 | 0.792 |
| | | 4.0 x 4.0 | 6,219 | 3,676 | 4,693 | 526,316 | 0.0089 | 0.816 | 0.807 | 0.811 |
| | 5x4 | 3.0 x 3.0 | 8,587 | 3,182 | 5,344 | 526,316 | 0.0102 | 0.757 | 0.766 | 0.762 |
| | | 3.5 x 3.5 | 7,410 | 2,886 | 4,696 | 526,316 | 0.0089 | 0.791 | 0.793 | 0.792 |
| | | 4.0 x 4.0 | 6,495 | 2,755 | 4,251 | 526,316 | 0.0081 | 0.816 | 0.807 | 0.811 |
| | 5x5 | 3.0 x 3.0 | 7,824 | 3,811 | 5,416 | 526,316 | 0.0103 | 0.757 | 0.766 | 0.762 |
| | | 3.5 x 3.5 | 6,888 | 3,633 | 4,935 | 526,316 | 0.0094 | 0.791 | 0.793 | 0.792 |
| | | 4.0 x 4.0 | 6,159 | 3,602 | 4,624 | 526,316 | 0.0088 | 0.816 | 0.807 | 0.811 |

**Table 5**
**Outflow Simmary (220,000 CDWT – 450,000 CDWT)**

## Proposed Standard

The mean outflow parameters are displayed as a function of the cargo capacity in Figure 4. The dashed line represents a proposed standard for mean outflow. In Table 6, designs are sorted by mean outflow parameter. The IMO reference ships are identified with double lines.
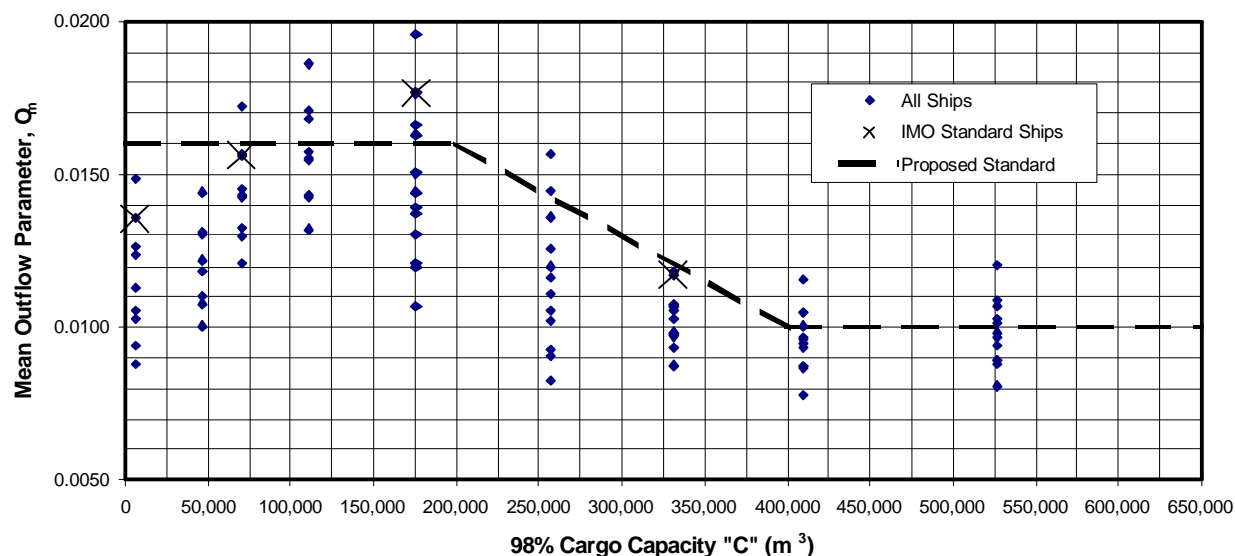


**Figure 4**
**Mean Outflow Parameters**

**98% CARGO CAPACITY**

| 5,000 MT 5,849 m³ | 40,000 MT 46,784 m³ | 60,000 MT 70,175 m³ | 95,000 MT 111,111 m³ | 150,000 MT 175,439 m³ | 220,000 MT 257,310 m³ | 283,000 MT 330,994 m³ | 350,000 MT 409,357 m³ | 450,000 MT 526,316 m³ |
|---|---|---|---|---|---|---|---|---|
| **Standard 0.0160** | **Standard 0.0160** | 5x2 2.0x2.0 0.0172 | 5x2 2.0x2.0 0.0186 | 5x2 2.0x2.32 0.0196 | 6x2 2.5x2.5 0.0157 | **Standard 0.0121** | 5x3 3.0x3.0 0.0116 | 5x3 3.0x3.0 0.0121 |
| 5x2 1.0x1.1 0.0148 | 5x2 2.0x2.0 0.0144 | **Standard 0.0160** | 5x2 2.5x2.5 0.0171 | 6x2 2.0x2.32 0.0177 | 7x2 2.5x2.5 0.0145 | 5x3 3.0x3.0 0.0118 | 5x3 3.5x3.5 0.0105 | 6x3 3.0x3.0 0.0109 |
| 6x2 1.0x1.1 0.0136 | 6x2 2.0x2.0 0.0131 | 5x2 2.25x2.25 0.0157 | 6x2 2.0x2.0 0.0168 | 5x2 2.5x2.5 0.0166 | **Standard 0.0143** | 5x3 4.0x2.0 0.0117 | 6x3 3.0x3.0 0.0105 | 5x3 3.5x3.5 0.0107 |
| 7x2 1.0x1.1 0.0126 | 5x2 2.25x2.25 0.0130 | 6x2 2.0x2.0 0.0156 | **Standard 0.0160** | 7x2 2.0x2.32 0.0163 | 6x2 3.0x3.0 0.0136 | 5x3 3.5x3.5 0.0107 | **Standard 0.0100** | 5x5 3.0x3.0 0.0103 |
| 5x2 1.25x1.25 0.0124 | 7x2 2.0x2.0 0.0122 | 7x2 2.0x2.0 0.0145 | 5x2 3.0x3.0 0.0157 | **Standard 0.0160** | 7x2 3.0x3.0 0.0125 | 6x3 4.0x2.0 0.0107 | 5x5 3.0x3.0 0.0100 | 5x4 3.0x3.0 0.0102 |
| 6x2 1.25x1.25 0.0113 | 6x2 2.25x2.25 0.0119 | 5x2 2.5x2.5 0.0143 | 7x2 2.0x2.0 0.0156 | 6x2 2.5x2.5 0.0150 | 6x2 3.5x3.5 0.0120 | 6x3 3.0x3.0 0.0107 | 5x4 3.0x3.0 0.0097 | **Standard 0.0100** |
| 7x2 1.25x1.25 0.0106 | 5x2 2.5x2.5 0.0118 | 6x2 2.25x2.25 0.0142 | 6x2 2.5x2.5 0.0155 | 5x2 3.0x3.0 0.0144 | 5x3 2.5x2.5 0.0116 | 5x5 3.0x3.0 0.0105 | 5x3 4.0x4.0 0.0096 | 5x3 4.0x4.0 0.0098 |
| 5x2 1.5x1.5 0.0103 | 7x2 2.25x2.25 0.0110 | 7x2 2.25x2.25 0.0132 | 6x2 3.0x3.0 0.0143 | 7x2 2.5x2.5 0.0139 | 7x2 3.5x3.5 0.0111 | 5x5 4.0x2.0 0.0103 | 6x3 3.5x3.5 0.0095 | 6x3 3.5x3.5 0.0097 |
| 6x2 1.5x1.5 0.0094 | 6x2 2.5x2.5 0.0108 | 6x2 2.5x2.5 0.0130 | 7x2 2.5x2.5 0.0143 | 5x3 2.0x2.32 0.0137 | 6x3 2.5x2.5 0.0106 | 5x4 3.0x3.0 0.0098 | 5x5 3.5x3.5 0.0093 | 5x5 3.5x3.5 0.0094 |
| 7x2 1.5x1.5 0.0088 | 7x2 2.5x2.5 0.0100 | 7x2 2.5x2.5 0.0121 | 7x2 3.0x3.0 0.0132 | 6x2 3.0x3.0 0.0131 | 5x3 3.0x3.0 0.0102 | 5x5 3.5x3.5 0.0098 | 6x3 4.0x4.0 0.0087 | 6x3 4.0x4.0 0.0089 |
| | | | | 7x2 3.0x3.0 0.0121 | 6x3 3.0x3.0 0.0093 | 6x3 3.5x3.5 0.0097 | 5x4 3.5x3.5 0.0087 | 5x4 3.5x3.5 0.0089 |
| | | | | 5x3 2.5x2.5 0.0120 | 5x3 3.5x3.5 0.0091 | 5x4 4.0x2.0 0.0094 | 5x5 4.0x4.0 0.0087 | 5x5 4.0x4.0 0.0088 |
| | | | | 5x3 3.0x3.0 0.0107 | 6x3 3.5x3.5 0.0083 | 5x4 3.5x3.5 0.0088 | 5x4 4.0x4.0 0.0078 | 5x4 4.0x4.0 0.0081 |

**Table 6**
**Mean Outflow Parameters**

All IMO reference ships fall within the proposed standard except the 150,000 (SUEZMAX) design. The reference ship has a 6x2 tank arrangement with a 2.0 m wing tanks and 2.32 m double bottom. In order to satisfy the proposed standard, and increase in the wing tank and double bottom dimensions to about 2.4 m x 2.4 m is required. As illustrated in Figure 5 and Figure 6, most of the SUEZMAX tankers constructed in recent years have clearances exceeding 2.4 m. This is primarily due to structural and access considerations.
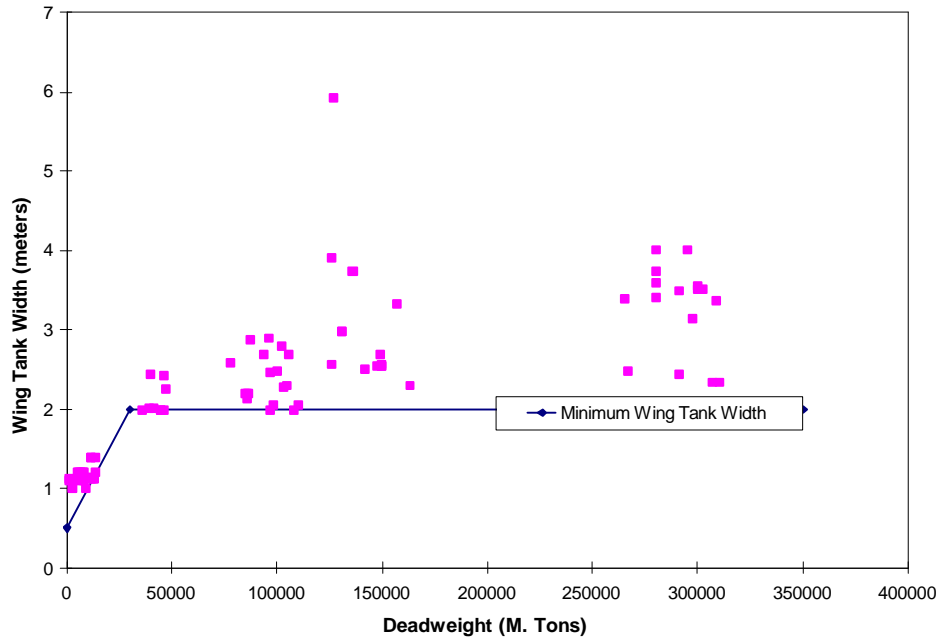


**Figure 5**
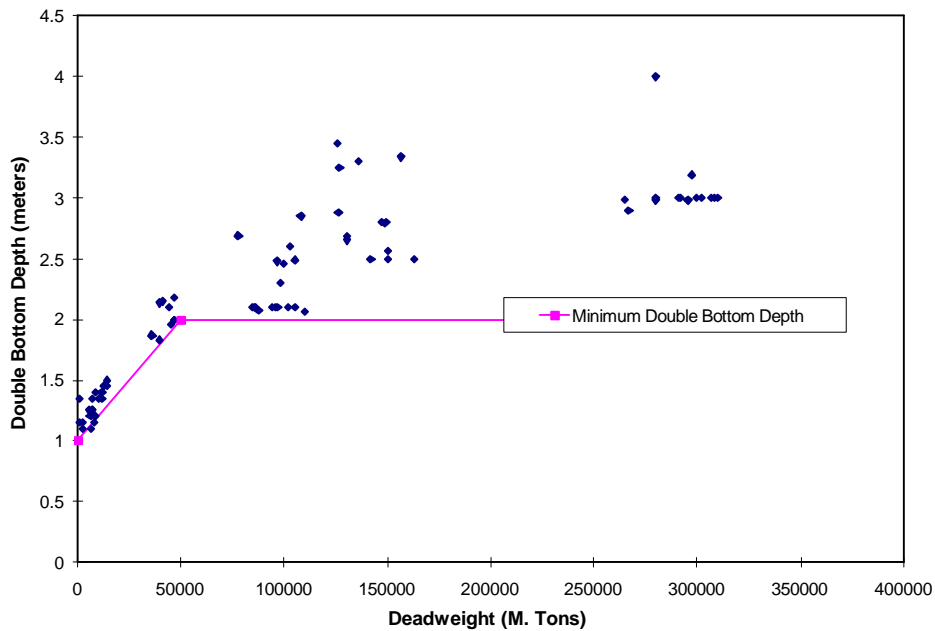**Wing Tank Width (for Recent Double Hull Tankers)**



**Figure 6**
**Double Bottom Depth (for Recent Double Hull Tankers)**

Anticipated impact of this proposed standard is as follows:

- The standard will likely eliminate future tankers with "single tank across" cargo tanks. For instance, a 40,000 DWT tanker with a 7x1 cargo tank arrangement would require 4.25 m deep wing tanks and double bottoms in order to satisfy this proposed outflow standard. It should be noted that, due to intact stability as well as outflow considerations, few (if any) "single tank across" tankers are under construction today.

- AFRAMAX tankers (about 95,000 DWT) with minimum 2m x 2m double hull dimensions will need a 7x2 or greater cargo tank subdivision. The double hull dimensions must be approximately 2.3 m or perhaps 2.4 m if a 6x2 cargo tank arrangement is used.

- Most SUEZMAX tankers under construction utilize a 6x2 (or greater) cargo tank subdivision, and 2.4 m or greater double hull dimensions. The proposed standard will not influence these designs. It will eliminate the occasional design built to minimum double hull dimensions.

- Most VLCC's under construction utilize a 5x3 (or greater) cargo tank subdivision, and 3m or greater double hull dimensions. The proposed standard will not influence these designs. It will eliminate the occasional design built with wing tank clearances below about 2.8 m.

Thus, the proposed standard will effectively eliminate "single tank across" arrangements, which have been shown to exhibit poor outflow characteristics. It will also influence double hull dimensions for some AFRAMAX (and larger) designs. However, most tankers under construction today will meet the proposed standard.

**References**

1. "Draft Regulation on Hypothetical Outflow of Oil", BLG 2/4, 1996.

2. "Report of the working group at BLG 2 (part 2) on Revision of MARPOL Regulations I/22 to 24 in the Light of the Probabilistic Methodology for Oil Outflow Analysis", 1997.

3. "Interim Guidelines for the Approval of Alternative Methods of Design and Construction of Oil Tankers under Regulation 13F(5) of Annex I of MARPOL 73/78", Resolution MEPC.66(37) adopted September 14, 1995.